THE HABITS OF INSECTS AS A FACTOR IN CLASSIFICATION.*

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There is, I presume, at the present time a very general agreement among systematists that our systems of classification should represent something more than a convenient placing of groups in divisions in which they may be discovered by some key. Certainly all naturalists who look into the significance of relationship must wish to see their classification represent what they can discover in the way of natural affinity or the lines of derivation of the respective groups. It is also, I presume, a common if not universal experience that in every piece of systematic work there remains at the end some unsolved problem or some remnant of uncertain species that cannot be placed to the satisfaction of the worker. It is not my expectation that I can solve these perplexities in a short discussion of the criteria for taxonomic work, but it appears to me that we may secure some assistance and reach, perhaps, more satisfactory results if we bring to our assistance in this difficult field as many as possible of the factors which have been concerned in the differentiation of species, and, therefore, a recognition of the characters by which species and the larger taxonomic groups may be separated. Of these different factors the habits associated with the life of insects is one which should doubtless be given much greater attention than has been our practice in most of our systematic work. In large part, of course, this is due to the fact that we have been compelled to work with collected material of which we knew practically nothing as to environment or habit, or sometimes, even as to the more general ecologic conditions. Such data ought to be considered more and more an essential part of the basis of classification.

Insects doubtless serve as well as any of the great groups of animals for the illustration of any biological principle, and it is my belief that almost every important principle in biology may be studied and elucidated within the group. What is said here about insects may, therefore, in large part be applied to other

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groups of animals, but I wish especially to speak of this group. No better audience for such a subject could be possible than one including so many who are devoting a large amount of valuable time and effort to the perplexing problems of insect classification.

Some twenty years ago our worthy president, Professor Comstock, published a remarkably suggestive paper on Evolution and Taxonomy in which he set forth in a masterly manner the idea that what we believe in evolution should be used as a basis in our taxonomic work, or that our systems of classification should show the lines of evolution of the various groups. Since then some papers have made good use of this general principle, but there are still many groups in which current classifications have largely ignored the principle or sadly distorted it in interpretation.

Perhaps if we agree on the principle we have used unfortunate methods in determining its application, and it is with the hope of showing possibly a little more clearly one of the helps in determining this point that I propose to discuss the habits of insects in connection with the possible aid they may give us in tracing the lines of evolution.

Primitive insects which we may conceive to have been largely terrestrial in habit have diverged along certain main pathways such as adaptation to aquatic life, underground existence, arboreal life, sedentary condition, parasitic habit, gall making habit, and a host of minor lines of special adaptation. To bring out their significance we may best review somewhat hurriedly some of these lines of divergence.

SUBTERRANEAN LIFE.

The tendency of insects to burrow underground is perhaps one of the more primitive lines of adaptation, as it may very easily be seen to come from their efforts at concealment, to escape enemies, to avoid light, or in arid regions to escape excessive heat, and in many groups as the simplest mode of pupation. From the more general form, however, we find in almost every order cases of especially adapted species or sometimes whole genera or families including varying degrees of adaptation to underground life. Mole crickets are the most perfectly adapted of the Orthoptera, but indications of the easy stages in this group are shown by crickets and stone crickets which are less perfectly fitted for such life. A group taking these features into account would evidently place the mole cricket as the extreme form in this line of adaptation.

Among Hemiptera we have numerous cases of subterranean adaptation, the most of the Cicadas, the root inhabiting Fulgoridæ, Cercopidæ, Membracidæ, and the highly specialized underground species of Aphids and the burrowing Cydnidæ showing a drift in this direction. The Cicadidæ are extremely specialized for such life, and the nymphal stages profoundly modified, showing a long ancestry of underground life. Among the Fulgorids, Membracids and the Cercopids it occurs in isolated forms and in these is in most cases of recent origin. Among the Aphids many species of Rhizobius, Pemphigus and Schizoneura show this adaptation, often greatly complicated with association with ants and by alternation of food plants or different root and leaf feeding forms. In every case, however, there is the best of evidence of the derivation of these root living forms from an ancestry that lived only above ground, and hence a clue to their systematic relationships is easily found.

The ant lion is a special case of adjustment and a striking contrast to the aquatic and terrestrial members of its order. In the construction of its pit-falls it shows a plan of underground life that differs strikingly from that of any other insect and is so distinct that it may be considered a good family character.

In Coleoptera the underground habit is distributed among many different families, but is especially characteristic of the Scarabæidæ in a large section of which the underground condition prevails for all but a short period of adult life. Here there is a very distinct and extreme adaptation both in the matter of food and adjustment to soil that fits them for this condition. Among the flies we have the burrowing larvæ of the crane flies and the Bibionidæ.

Among the butterflies and moths we have but little adaptation to underground life aside from the burrowing into the ground for the purpose of pupation, but cut worms and sod worms spend a considerable portion of their larval life in the soil, though feeding for the most part above ground. The bees, ants and wasps present us with a number of extreme forms of underground habit, but this is in many cases associated with community life. In fact community life seems very likely to have originated in nearly every case from the insects which had adapted themselves to this sort of existence. Some sort of protection such as cavities in the ground or in rocks or trees may have been an essential factor in the development of community life.

ADAPTATION TO AQUATIC LIFE.

The insects which live in the water show very distinct lines of divergence from the terrestrial habit and we can trace in a great many different groups the connection with the land inhabiting forms with very great certainty.

There is at present probably no question as to the general principle of the derivation of aquatic forms from those inhabiting the land, but the relations of the different groups and the particular lines of adaptation are open to further study. One feature that is perhaps sometimes overlooked is that the groups in which the aquatic habit is most perfectly established are those which have been for the longest time fitted for such existence, and therefore show less perfectly the connection with land inhabiting forms. The groups of dragon flies and May flies may both be looked upon as having established the aquatic habit at a very remote period, and as showing at present a very perfect adjustment in the larval stage for this mode of life. In both of these groups the larvæ are capable of aquatic respiration and have been provided with tracheal gills, adapted on different lines, so that they need not come to the surface in order to gain air. The development of these tracheal gills, however, must have been a matter of long evolution, but the fact that they are associated with a complete but modified tracheal system is evidence of their origin, subsequent to that of trachea.

In the mosquito, on the other hand, we have forms in which such a perfect aquatic respiration is not developed, the larvæ, in nearly all species, being obliged to make frequent trips to the surface of the water in order to acquire fresh supplies of air. And here, too, there is a distinct interchange of the contents of the tracheal tubes permitted by the open spiracles. A more specialized condition is shown in the buffalo gnats where there is a development of gill filaments capable of absorbing oxygen from the water and permitting strictly aquatic respiration without any recourse to the atmosphere. It has lately been shown, however, that tracheal tubes are present but become much reduced in these gill filaments so that there is every reason to assume that the aquatic respiration is of comparatively recent origin.

In the aquatic Hemiptera we have a series of families which show successive stages of adaptation to aquatic life, and we may trace by easy stages the passage from land or shore living forms to those which are most completely specialized for aquatic life.

The water striders which live entirely on the surface of the water have a rather special adaptation, but with the Naucoridæ we reach a group in which the aquatic life is well established. These insects have their form well fitted for swimming, but their respiration is dependent upon the atmosphere, and they must make frequent trips to the surface. Somewhat more specialized are the Belostomidæ in which the ability to remain under water is very perfectly developed, but without special gill structures for aquatic respiration. The Nepidæ go further in that they have long tubular structures which permit them to reach the surface of the water without bringing the body up to the surface. The water boatman and Corixa, though not more specialized in these features, show in some other respects a more perfect adaptation and are to be considered as among the most extreme of the aquatic groups. It seems to me apparent from such a series as this that the arrangement of groups should be made to correspond as closely as possible with the successive stages in specialization for the particular habitat which is present. That these insects are descended from strictly terrestrial forms seems certain, and that their various adaptations represent different degrees of perfection in adjustment to the new habitat will, I believe, fit in most perfectly with the comparative study of their structure. It is shown, perhaps, most decidedly in the condition of the antennæ and in the modifications of the legs in adaptation to swimming.

Most of the aquatic beetles appear to have but recent adaptation to this habit, as all are obliged to secure air from above water, and in most species a considerable ability to live outside the water is present. It is also quite certain that the aquatic habit has in this group been acquired independently in the different families.

With the evidence that may be accumulated in all the different orders of insects it seems certain that in every group of insects having aquatic habits we may confidently trace a derivation from terrestrial ancestors, and hence in arranging phylogenies we may consider that those less perfectly adapted are the more primitive and those most perfectly fitted for aquatic life are the most specialized. This will involve some radical changes from accepted and time honored systems of classification, but will, I believe, in every instance result in more rational and satisfactory groupings.

THE SEDENTARY HABIT.

Insects in many different groups show a tendency to become fixed for part or all of the life cycle, and in some cases they reach very extreme conditions in this direction. It is most pronounced in the group of Hemiptera, and in this group it shows a very complete series of gradations from the free forms to those which are most extremely sedentary. In the Psyllidæ for example there are some forms which show a tendency toward attachment during the larval stages, but in others this is modified into the gall infesting habit. In the white flies there is fixation during the larval and pupal stages with the free adult. In Aphids there are many species which attach themselves by the mouth parts and remain practically fixed for long periods. This is notably true of such species as the beechblight, alderblight, wooly aphis and others. Among the scale insects we have the most extreme condition, but there are gradations from such free forms as the mealy bugs and the Orthezias through the unarmored scales to such very extreme forms as the Diaspids. There can be no question, it seems to me, that these series show the lines of divergence and that the more extreme attached species must have descended from those which had greater freedom, and that the sedentary habit has in this group become more and more fixed.

Some of the moths show a considerable tendency to fixation, and examples such as the case bearers and bag worms and the tussock moths show steps in the direction of fixation for certain portions of their existence.

COMMUNITY LIFE.

The community life in insects is another very striking line of adaptation and one in which we can see most positively the gradual derivation from the more primitive forms in which communal life is unknown. In its simplest condition it may be considered as represented in the aggregation of larvæ which remain and feed together for a considerable period, but in which there is nothing more than a mutual protection, construction of tents or other devices, and no development of distinct kinds of individuals as a result of social habit. We have, however, amongst the termites, the ants and the bees, extreme cases where the community habit resulted in a very striking production of different kinds of individuals in a colony, these being adapted to carrying on entirely different activities. While termites, ants and bees must be con-

sidered as having acquired the community habit independently, they have very distinct parallelism in the kinds of individuals which are produced. In all cases there are normal males and females and also a class of non-sexual individuals or neuters, but in both termites and ants these neuters have been further differentiated into forms which carry on different kinds of activities in the colony, as for instance workers and the soldiers. In some ants these duties are still further subdivided and give rise to most perplexing series of polymorphic forms.

Those of us who had the opportunity to hear Professor Wheeler's brilliant address a year ago will remember how remarkably these polymorphic forms have been developed and can appreciate also how essential a recognition of the functions and the lines of adaptation for these forms must be, in order that anything like rational arrangement of the species may be made.

Community life in birds, beaver, fur-seal, sheep, cattle and even in the human species has not by any means the extreme condition of specialization seen in some species of these insects that have been mentioned. Nowhere does it show anything like so profound a change in the economy, structure or the relations of the members in the community.

PROTECTIVE DEVICES.

In the way of special adaptation for protection, insects show a wonderful variety of forms and have been one of the favored groups for the illustration of this general practice in nature. We can illustrate it by the use of certain forms among our common species such as the gypsy moth which with its color and marking has become very perfectly adapted for protection on the bark of the birch which appears to have been its native food plant, as shown by Prof. C. H. Fernald at the Boston meeting. Our common luna moth probably illustrates this also, since its coloration is well adapted for protecting it among the leaves of its most common food plant. It appears also that the long tail of the hind wings may very likely assume the position of the petiole of the leaf, and therefore fit in very perfectly with the surroundings of the insect. I have been struck by this particular feature in seeing the moth resting in such a position as to simulate closely an attached leaf. Among the leaf hoppers there are a number of species which show a very complete adaptation in this direction. Nearly all of the species of Deltocephalus if noticed

in connection with the plants on which they are feeding will be found to have, both in color and shape, a most perfect protection in connection with the plants on which they are attached. In the little Lonatura there is not only a distinct similarity in the size and color of the small stems of its host plant, but there are short winged forms which fit in at certain seasons of the year still more perfectly with the food plant or the debris on the surface of the ground in which they may be collected. Driatura in the long and short winged forms appears at first sight to be rather conspicuous, but if taken in connection with the places where it lives is found to blend most perfectly with its surroundings and to be thereby very perfectly protected. Perhaps the most striking example among our native species is to be found in the genus Dorycephalus which lives upon the stems of large grasses, and in this form the head is very much elongated, the wings shortened, and the color so perfectly straw-like that upon the stem of the plant the insect becomes entirely invisible. The males are dark in color with longer wings, and probably rest more continuously on the darker portions of the dried leaves. A still further adaptation occurs with the young which collect in the heads of the plant and which resemble most perfectly the glumes of the seeds. So perfect is the adaptation in this form that none of the stages are readily found and it is only by beating the plants that they may be collected. A related species (D. vanduzei) occurring on smaller stemmed plants is perhaps even more distinctly specialized, the wings being more reduced and the body more elongate.

Another case which is especially striking is found in a small capsid which lives at the surface of the ground and which in the female is entirely wingless and the body so modified as to very perfectly resemble an ant. This resemblance does not stop with a superficial similarity, but may be noticed even in the basal segments of the abdomen which simulate in a striking manner the same segments in the abdomen of the ant. The male of this species is longed winged, very strikingly different from the female, and doubtless lives under quite different conditions, making use of its wings and flying readily from place to place.

Another quite striking case is to be found in the beach grasshopper which is common to sand dunes and beaches throughout a quite extended range of the United States. This species shows most perfect adaptation for protection on the surface of the sand, the spots and marking on the body blending so perfectly with the

color and form of sand grains that when at rest it is quite invisible. In the photograph shown the outline is indicated by shadows which were really necessary in order to make it apparent, but it may easily be seen, that without these it would be extremely difficult to discover the insect. Now none of these adaptations can be thought of as primitive but rather as highly specialized forms derived from an ancestry of more general habit. Ought this not to be recognized in their classification?

GALL MAKING INSECTS.

Another quite distinct line of divergence for insects is found in the gall making habit, a habit which involves not simply the action of the insect, but the stimulation by the insect of a certain plant activity that results in an abnormal growth which is of service to the insect either as a source of food material, or for protection, or both. That this adaptation occurs independently in many different groups of insects is clearly evident if we consider the distribution of the gall making groups. It is present even in the Acarina, species of which produce a very great variety of galls on many different plants. Among the true insects the aphides contain a considerable number of gall making species, and in some of these the galls are quite elaborate in structure. The Pemphiginae found on elms and poplars show very distinctly formed structures such as the poplar leaf gall. In the genus Phylloxera which is distinctly a gall making genus we have the common grape species and numerous species affecting the hickory, in all of which there is a very distinct gall for each species. The Psyllidae are distinctly gall making and the galls produced are very characteristic, and the whole life of the insect is adapted to this method of existence.

Among the beetles we have a number of gall making species, those of the genus Agrilus perhaps being the most distinctive, but it is evident that the gall making habit in this group is entirely independent of that in any other order, and even of any other family of the group of beetles. In the Diptera several families include gall making species, but the gnats are most distinctly developed in this direction. We have, however, every gradation in this family from species that are not gall makers up to those which produce the most perfect and constant forms, for example, the Hessian fly, willow galls and the grape filbert galls.

Of the Lepidoptera comparatively few gall makers are known, but amongst the tineids we find gradations from miners to gall makers.

Among the sawflies there are several genera which live entirely in galls and here again quite complete gradations may be observed from the more general mode of life to the distinctly gall making form. The most distinctly gall making group, the Cynipids, presents us also with almost every possible gradation from the simple attack on leaves to the formation of very elaborate gall structures, and by careful comparison of different forms we can trace with considerable sureness the lines of divergence for each of the species and their relative departure from primitive forms.

WOOD BORING INSECTS AND BARK BEETLES.

Of the insects that work into the substance of woody plants we have a considerable number, and many of them illustrate a long course of adaptation to this particular form of life. The termites show an extreme ability to tunnel into wood and devour the interior of large masses of woody structures, and for this purpose have the mouth parts considerably specialized. The habit, however, is associated with the community habit which is discussed under another head. Among the Lepidoptera we have several families in which this mode of life has been quite fully developed, the most striking forms being the Cossidæ including the large carpenter moths, the larvæ of which tunnel deeply into various hard wood trees, and the Sesiidæ, practically the entire family being specialized for this habit. It shows, however, considerable degrees of adaptation, the peach borer living mainly just beneath the bark in shallow cavities which may open to the surface, while in the Syringa borer, Currant borer and some others, the central portion of the stem or trunk of the tree is invaded. Among the beetles the family of long horned borers (Cerambycidæ) is among the most characteristic, and excepting a few forms such as the milk weed borers are adapted for penetrating deeply into very hard wood. The Hickory borer for example tunnels into the heart wood of Hickory, requiring a period of two or three years for its growth. The Locust borer, Poplar borer, and the familiar Apple borer are other well known examples. Again in the Buprestidæ we have a distinctly wood boring group, although in these the borers are usually confined to the younger wood or cavities beneath the bark. They show perhaps less

complete specialization for boring, but in the flattened form of young and adult show adaptation to the particular portion of the tree which they affect. The bark beetles present a somewhat different condition, but are no less distinctly specialized for their particular habitat. They live for the most part between the bark and hard wood and construct intricate tunnels sometimes of most peculiar pattern, and frequently occasion very great injury to the trees infested. The habit in these different groups has very evidently been reached by entirely independent routes and the lines of adaptation must be traced in each group separately. Often the particular steps of adaptation are very beautifully shown in the series of species which illustrate the divergence from external leaf eating forms to those which are most perfectly fitted for living within the plants.

Of the Hymentopera the horn-tail borers are the most distinctly specialized in this direction, and these show a derivation from the leaf feeding saw-fly forms. The ants and bees which burrow into wood or into the stems of plants show certain other forms in which the habit has been adopted by isolated small groups, but not adopted by the larger divisions.

THE PARASITIC PATHWAY.

In the direction of parasitic life some groups of insects have traveled very far and show almost as distinctly as any group of animals the effects of the parasitic life. So numerous are the examples in this line that we must select only a few of those which are most specialized or which illustrate most perfectly the lines of derivation for the habit. In the Mallophaga we have a group in which the parasitism is distinct for all the known species and in which the result of parasitism is shown in the entire absence of wings and in the very perfect adaptation of clasping organs in the feet. In their mouth parts and other structure, however, they show very perfectly their derivation from some psocid ancestor, and by selecting series of genera we can trace quite clearly the different steps in adjustment from forms which are but slightly parasitic to those which are most extremely dependent upon their attachment to a host. In some cases migration from one kind of animal to another is possible and probably frequent, but in other species more strikingly specialized there is a most rigid restriction to a single species and absolute dependence upon the association of individuals in that species for its distribution and survival.

The bot flies illustrate remarkably well the degrees of specialization in the parasitic life, the sheep bot which lives in the frontal sinus of the skull representing a much less important departure from a non-parasitic form than the horse bot which lives within the stomach and must be adapted not only to a special mode of nutrition but to a particular limitation in the matter of respiration, a feature which goes still further in the case of the ox bot with its circuitous route from egg through alimentary tract to its final resting place beneath the skin. We cannot conceive this latter form of adaptation except as a derivation from the more simple form of parasitism, and our classification in this group may well take this into consideration. A particularly extreme form of parasitism with the results of parasitic life is exhibited in the sheep tick and its allies where there has been not only a striking modification of the structures of the body, but a profound modification in its mode of development. In this it shows an extremity which is perhaps not exceeded by any other group of animals though paralleled by the parasitic Stylopidæ, and in every detail of which we must recognize the effect of the parasitic life. The other forms of parasitism such as the occupancy of the nest of bees by flies or other species of bees which occur in a bewildering number of intricate forms cannot be dwelt upon here. The remarkable adaptations of such parasitic forms as the Ichneumons and Chalcids in their adjustment to plant lice and scale insects, and the egg parasites in their extreme adjustment to the completion of a life cycle within the minute egg of some other species of insect, cannot fail to occur to all who have become at all familiar with the complexities of insect life.

I may perhaps be permitted to further illustrate this idea with one other example drawn from a group which has been one of my special studies. The Pediculidæ are, I will grant, a not very popular division of insects and yet in some of their adaptations and in the long course of parasitism which they seem to have undergone, they give us some of the most positive evidences as to the effects of the parasitic habit and also as to their course of evolution. We may readily appreciate their long adoption of the parasitic habit when we consider the wide divergence they show from other groups of insects, and the range of their hosts, and yet we must assume beyond question that their establishment as a parasitic group has been subsequent to the evolution of the group of mammals of which they are exclusively parasites.

I have elsewhere indicated my belief that the group originally came from some division of the Heteroptera and I am still skeptical concerning the recent attempts to relate them to Mallophaga, but for the present study this point is not essential. Granted a primitive form assuming the parasitic relation to some primitive mammal and we have the materials on which to construct a tentative phylogeny which we may test by such evidences from morphology, distribution and habit as may be available.

There are of course at least two plans on which we may account for the present distribution of the species of this family. One that the primitive parasitic form appeared at some time in the early history of the mammalian stem and that its subsequent history and the divergence of the various species has gone along parallel with the divergence of the host forms; the other that it appeared much later in history after the establishment of the mammalian groups and that from an establishment on some one group of animals it migrated to other mammals and the various species developed on new hosts by more recent evolution. The fact that most of the species have a single host to which they are restricted gives unusual opportunity to test any theory of evolution.

Confining ourselves to the Pediculidæ, although it would be interesting also to examine the relation of the Polyctenidæ occurring on bats, we have a group showing very clearly a common origin and possessing some very homogeneous characters, the most evident the single jointed rostrum and the single clawed tarsi. The separation of the genera has always seemed somewhat arbitrary and based as a matter of necessity in such simple forms on rather trivial characters, but some of these characters take on entirely new significance if correlated with the distribution of the genera with reference to their hosts.

It will be noticed from the diagram (Pl. II) that the groupings of these parasites bear a distinct relation to the main divisions of the class of Mammalia. While this is not presented as an accurate statement of the phylogeny of the mammals, nevertheless it represents the remoteness of some of these groups and illustrates something of the possible relationships between them. Assuming that the primitive parasitic group established itself on a primitive mammal, we can follow the divergence of the different groups with considerable assurance. There is a distinct type belonging to the group of rodents, another for the insectivora, another for

the ungulates, still another for the elephant, and a group covering the primates. Comparing these it appears that the ungulate and primate groups have really a closer relationship than either of these with the rodent forms, although in existing classifications the ungulate and rodent forms are embraced within the same genus. It appears to me more in accord with the facts, especially if we take into account this distribution and habit, to separate the rodent forms, and this will necessitate the forming of a new genus.

Clasping organs show distinct types for a number of these groups and quite varied forms in such apparently nearly related species as those affecting Horses, Hogs, Cattle, etc. The Insectivore type is extreme and introduces new features.

We have traced a few of the many lines of adaptation that have been followed by the groups of insects in their adjustment to the many and varied conditions of life; adjustments so numerous and so perfect that insects are today not only the most numerous in species but fitted to a greater range of conditions than any other class of animals. We certainly should take account of these different conditions in our systems of classification if we hope to have them represent the true relationships in nature. We should use the lines of divergence in habit to point the way to natural affinities. Distinct morphologic changes are almost invariably associated with adaptations, if indeed, they are not the direct response to these adaptations, and hence when habit, distribution, function and structure are read together, we should, if reading correctly most nearly approach the rational arrangement of groups.

I would not be understood as ignoring the fact that this principle has been recognized in the past. Such names as Phytophaga and Parasitica in Hymenoptera, Phytophaga, Mycetophaga, Hydrophilus, Gyrinus, Cryptophagus, etc., in Coleoptera, or such specific names as aquaticus, arborea, sub-terraneus, cavicola, etc., testify to due appreciation of habits by many systematic workers. But I wish to emphasize my belief that this principle may be used to advantage not only in tracing larger phylogenetic lines but in solving the perplexities of specific affinities among the minor taxonomic groups.

Students of animal behavior and psychology are beginning to associate the differentiation of groups with psychic characters, and such a claim as physiological species is not new even to ento-

mologists. It is evident that if systematists would keep their field of work abreast with the movements in other lines it will be necessary to take into account all the factors that may seem to give evidence as to affinity.

It should be clearly appreciated, however, and I think will be recognized by entomologists as quickly as any body of naturalists that habit is only one factor, that while it has had a determining influence in producing structure it has so frequently occurred in parallel lines in different groups that fundamental structures based doubtless on the more remote habit, must be taken into account. To ignore this would carry us back to such inconsistencies as placing whales with fishes, or the parasitic insects, fleas, lice, bird-lice, etc., in one group, Aptera. We must fully determine the significance of the deeper adaptations as revealed in more fundamental character along with the superficial modifications of more recent habit.

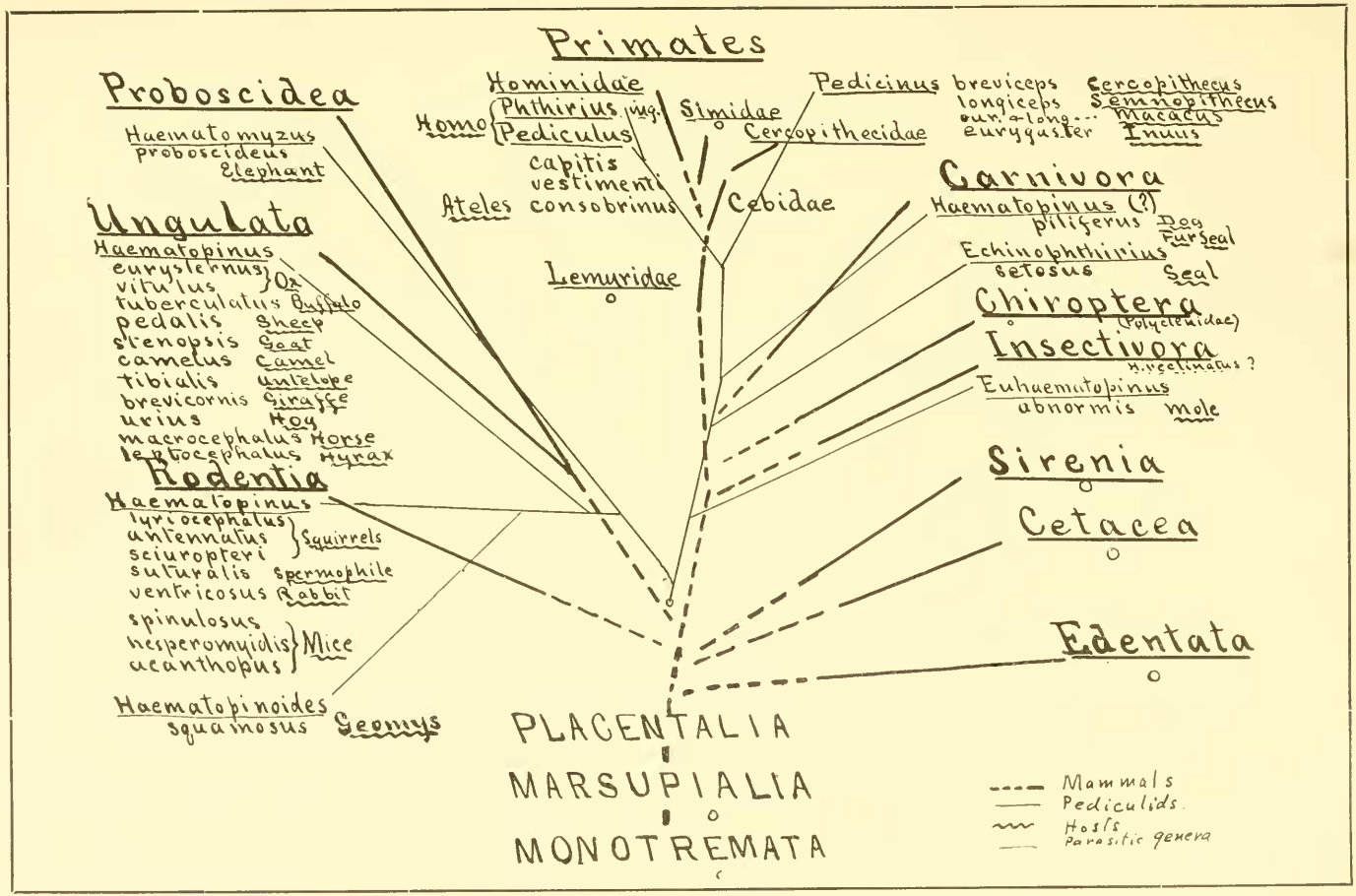

DIAGRAM ILLUSTRATING POSSIBLE LINES OF DIVERGENCE IN PHYLOGENY OF PEDICULIDAE.